LIBRARY
OF THE
MASSACHUSETTS INSTITUTE
OF TECHNOLOGY

HD28
.M414
no.334-
68

WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

A PLANNING PROGRAMMING BUDGETING SYSTEM FOR THE UNITED STATES GEOLOGICAL SURVEY

MASS. INST. TECH.
JUL 30 1968
DEWEY LIBRARY

334 - 68

by

Donald A. Belfer	Cyrus F. Gibson
Jonathan D. Casher	Paul W. MacAvoy
Peter G. Gerstberger	Quentin S. Meeker

MASSACHUSETTS
INSTITUTE OF TECHNOLOGY
50 MEMORIAL DRIVE
CAMBRIDGE, MASSACHUSETTS 02139

A PLANNING PROGRAMMING BUDGETING SYSTEM FOR THE UNITED STATES GEOLOGICAL SURVEY

MASS. INST. TECH.
JUL 30 1968
DEWEY LIBRARY

334 - 68

by

Donald A. Belfer
Jonathan D. Casher
Peter G. Gerstberger
Cyrus F. Gibson
Paul W. MacAvoy
Quentin S. Meeker

RECEIVED
SEP 4 1968
M. I. T. LIBRARIES

In August, 1965 President Johnson directed the heads of Federal agencies to implement a new Planning-Programming-Budgeting System (PPBS) throughout the Executive branch of the Government. As an agency in the Department of the Interior, the United States Geological Survey was required to respond to this directive but, like many other Executive agencies, was ill-equipped to carry out such implementation. The Survey was handicapped by the lack of well-defined objectives which could be readily translated into plans amenable to Planning-Programming analysis. The agency was staffed, as well, by professional geologists and scientists without experience in economics, quantitative analysis, or the related disciplines needed for installing systems analysis.

In the three years that have elapsed since the Presidential directive, the Geological Survey has not solved the very real problems involved in implementing PPBS. Its most difficult problem has been the identification of "output", and the measurement of that output's value to the users. Without estimates of the demands for the information produced by the Survey, calculation of benefits from the present activities of the Survey and economic comparison of these with alternative activities has been virtually impossible. First attempts have to be made to solve this problem, if only to indicate in detail what is not known. These attempts are made here.

The essay begins with a brief description of Planning-Programming-Budgeting in the federal government and of the current activities of the Geological Survey, as a frame of reference for raising the planning questions. From that point, it would be logical to begin the first of the PPBS systems analyses for this agency.

But this cannot be done with currently available information. We are confined to doing both more than and less than the first PPBS five year plan: more invention of analytical arguments for dealing with PPBS questions when information is severely lacking; less than the first draft of the operating plan for this agency. Illustrative first estimates of "benefits" are made without concrete demand estimates, and benefit-cost analyses are done for two Geological Survey programs, those in Regional Geology and in Engineering Geology. Conclusions are drawn on the "right size" for and "allocation of resources" in the mineral mapping activities of the Survey. Since PPBS is a process which must undergo continual evaluation and refinement, it is acknowledged at the outset that the results here are far from definitive and merely represent an attempt at the required first step under the worst conditions of information availability.

The Planning-Programming-Budgeting System

A new accounting frame of reference has many facets but of most interest are the presumed goals and the means for achieving them. The intent of this system is to promote economic use of resources. Accomplishing this goal requires a clear definition of national objectives within the agencies and departments of the Federal government, and the application of cost-effectiveness analyses to select optimal programs. The important link is between objectives or "long-range planning" and the annual budgeting process through cost effectiveness analysis.

A number of problems were resolved in the Department of Defense by the successful implementation of PPBS beginning in 1961. Two types of planning

were in effect -- military planning of weapons systems by separate services and budgetary planning of a shorter time span by the the civilian administrator-comptroller organization. The inherent differences among the services and the different approach of the budgetary planners led to unrealistically high aggregate budget requests for the Department as a whole. Allocation was handled arbitrarily by setting budget limits for services and sub-units down the line. Such a procedure aggravated the separateness of services' planning, with the result of an uncoordinated, unbalanced military organization. This was acknowledged by the budget makers: "Each service developed its own programs without any way to compare them systematically with competing programs of other services."[1] More important, it was acknowledged by those responsible for providing our defense capability: "As the budget examiners bore down, the Services held on to their most glamorous weapon systems. What normally gave way were the less glamorous support items: ammunition and equipment inventories, support personnel, spare parts, etc. The result was unbalanced forces that could not have been readily deployed into combat."[2]

Planning-Programming-Budgeting was to remedy this by relating proposed programs to one another through comparative cost-effectiveness analyses.[3]

---

[1] Schultze, Charles L., Hearings Before the Senate Subcommittee on National Security and International Operations, August 23, 1967.

[2] Enthoven, Alain C., Hearings Before the Senate Subcommittee on National Security and International Operations, September 27, 1967.

[3] Although some authors on PPBS distinguish between cost-effectiveness and cost-benefit analysis on the basis of highly technical conditions of costs and demands, these terms will be used here only to differentiate between(cont'd.)

The Defense analysts were to calculate the relative costs C_{it} for achieving one aspect of defense capability by alternative program "i" in year "t" and choose that program for which $\sum_t C_{it}/(1 + r)^t$ was a minimum -- or for which costs were most "effective". This goal was extended to non-defense agencies. The intent of the 1965 Presidential Directive was to create the framework for performing comparative analyses in all of the programs of the Federal Government.

The process is illustrated in Figure I. Included are the following components:

1. National Objectives. National objectives must be defined on the Presidential level, within the framework of the legislative process. They are basically political and general, yet guide the setting of more specific objectives at the agency level.

2. Agency Sub-Objectives. The relevant National Objectives[4] must be reduced by the agencies to economically comparable sub-objectives within the mission area. The importance of sub-objectives has been stressed by the President in order to "Make explicit the objectives of programs and relate them carefully to National needs;..."[5] If they are not formulated properly, the cost effectiveness analyses will compare irrelevant alternatives.[6]

---

[3] (cont'd. from p. 3) the least-cost alternative among mutually exclusive projects to achieve a predesignated objective (cost-effectiveness) and projects competing for resources by showing varying amounts of "benefits" from achieving various "objectives" per dollar of costs (benefit-cost analysis).

[4] There may, and in most cases will be more than one National objective applicable to any given agency. Each must be treated identically by the agency. For purposes of simplicity this description assumes only one.

[5] President Johnson's Budget Message to the Congress, January 24, 1967.

[6] Cf. Hitch, Charles J., and Roland N. McKean, The Economics of Defense in the Nuclear Age, Harvard University Press, Cambridge, Mass., 1960, p. 118.

3. Program Development. After attempting definitions of sub-objectives, the next step is to develop programs to accomplish them.[7] Within each program, as many specific alternatives (called Program Elements within the PPBS framework) as possible are identified and subjected to cost-effectiveness analysis. The final step in the process is the selection of more effective elements and the rejection of the less effective ones.[8]

All programs approved by the agency head are installed in the program structure. The development of the program structure lays the fundamental groundwork for the generation of both long-range plans and the annual budget submissions. This activity is shared with the Bureau of the Budget, which stresses that the programs should provide a suitable framework for analyses and decisions at the highest level within the agency and within the Executive Office of the President.[9]

The Formal Requirements in PPBS

The documents to be produced by the agencies are supposed to provide these results. The Bureau of the Budget, as the coordinating agency, has

---

[7] It will generally be desirable to further divide programs into sub-programs. However, the consideration of alternative sub-programs under a given program is analogous to the analysis of program elements and is, therefore, ignored in this discussion.

[8] Here the measurement of "benefits" or "effectiveness" is the most difficult task. The criteria for "utility" or "value", which should relate to agency sub-objectives, are indefinite and in many cases in contrast with those determining payments for government services.

[9] In preparing this package, the agency decision-maker examines the assumptions, both implicit and explicit, upon which the analyses are based and considers the effects of changes in these assumptions. If the accompanying analysis is inclusive and reasonably complete, the decision-maker will have the results of testing for the effects of changes in assumptions. Since projections into the future must contend with uncertainty, it is imperative that sensitivity testing be conducted for the most probable range of assumed conditions.

PPBS INFORMATION - DECISION FLOW

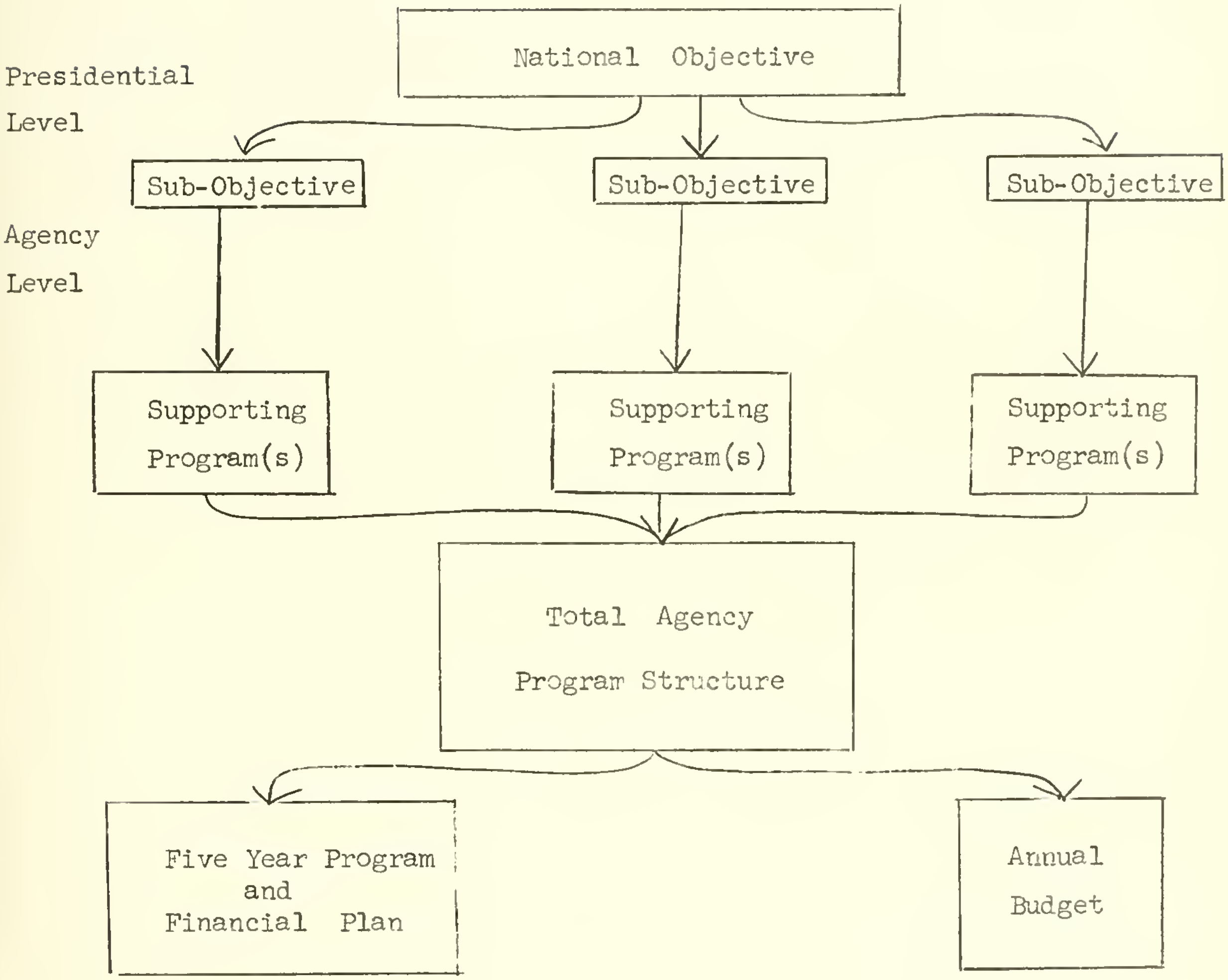


Figure I

developed a particular administrative process for implementing PPBS throughout the government. Four types of documents are required of each department and agency: program memoranda, a program and financial plan, special studies on cost effectiveness, and, finally, budget proposals.[10] These should show the linkage between objectives and programs,once all the documents have been assembled and reviewed.

Program Memoranda for each major program category are to be submitted to the Bureau of the Budget in the spring for the next fiscal year. Together they represent the "strategy upon which the agencies' future programs are to be (developed) and provide background for the development of annual budgets and legislation.[11] These define objectives, anticipate program accomplishments, and show what choices have been made. The Program Memoranda should clarify why particular choices have been made "by comparing alternative programs in terms of their costs and their achievement of objectives."[12] The documents outline not only the recommended programs but also the rejected alternatives to allow higher-level evaluation of these decisions. Where reductions must be made, for political or other reasons, the impact on an

---

[10] The outline is in Bureau of the Budget Bulletin No. 68-2, to the Heads of Executive Departments and Establishments: Planning-Programming-Budgeting (PPB) July 18, 1967.

[11] Ibid.

[12] Ibid.

EVOLUTION OF AN INDIVIDUAL PROGRAM

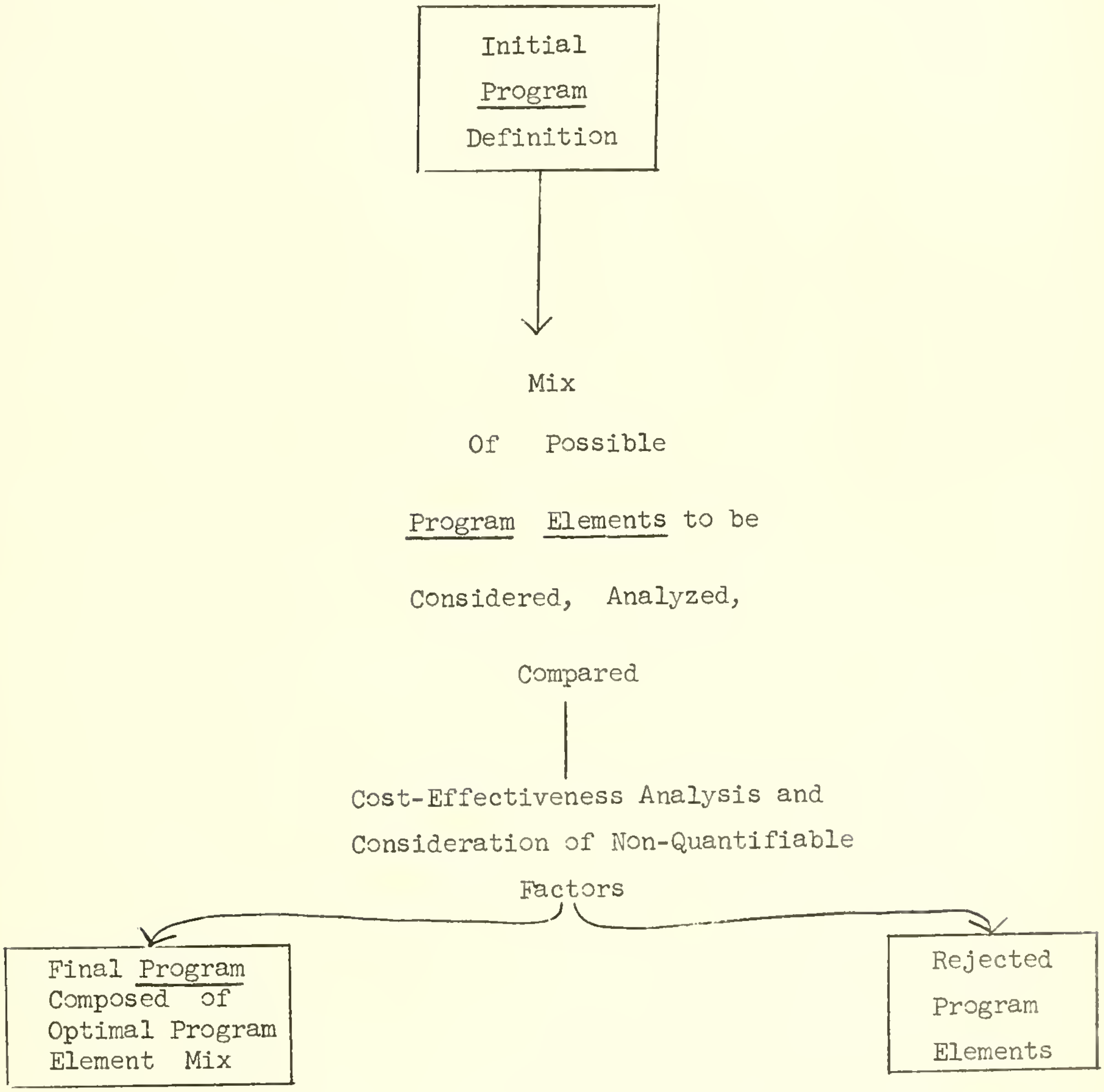

Initial Program Definition
Mix Of Possible Program Elements to be Considered, Analyzed, Compared
Cost-Effectiveness Analysis and Consideration of Non-Quantifiable Factors
Final Program Composed of Optimal Program Element Mix
Rejected Program Elements

Figure II

agency's programs will be visible not only in terms of reduced funds (input) but also in achievement of objectives (output). A final memorandum on each program is prepared by the agency after Bureau of the Budget review of the first drafts.

The final Program Memoranda set the framework for the Program and Financial Plan. This document lays out the inputs and costs of the currently proposed program structure, for the number of years required to complete the task at hand. It sets the frame of reference for financial outlays, even though it is not a "contract" between the agency[13] and the Budget Bureau but rather shows future cost implications of present decisions. Included in this plan is a so-called "cross-walk" table which breaks down costs both by traditional budget appropriation categories and by programs.

The Special Studies are detailed cost-effectiveness analyses underlying the recommended programs. Given that the Program Memoranda present decisions in summary form, Special Studies are intended to show detailed analytical results of program trade-offs. They are submitted whenever completed and do not follow any prescribed time pattern. They may be done at the request of the Bureau of the Budget, or on the agency's initiative. Unlike the other documents, the format for Special Studies is not fixed although their content generally includes a review of costs and benefits of prior program elements and analyses of net gains from incremental changes. Such a study should be made when new legislation is proposed to spell out the purposes, cost,

---

[13] The Budget Bureau stresses this: "The projection, therefore, is not designed to predict future budget totals for agencies or for major programs." (Ibid.)

alternatives, and expected accomplishments under the legislation.[14]

Budget Requests and Legislative Proposals, along with the Program Memoranda and the long-range Plan, are submitted to the Bureau of the Budget on 30 September to begin the evaluations of expenditures for the coming fiscal year. Although similar to the packages prepared prior to the introduction of PPBS, there are two distinctions: the budget is now submitted in a dual format, showing costs by program (output-oriented) and by appropriation category (input-oriented); where there are legislative proposals to be made, Special Studies are also submitted in support of them.

The PPBS procedure may be viewed as a circular flow (Figure III). The Presidency as the "center of initiative" sets national objectives which are realized most efficiently by agency program plans and modified by agency-initiated new legislation. But aspiration and performance aimed at efficient realization of objectives are far apart. Many agencies, like the Geological Survey, have been hampered by a lack of qualified staff to carry out the required analyses. In many cases sub-objectives have been difficult to formulate in a way that leads to analyses of competing programs. Particular problems of implementation develop when program structure set in output terms includes the overlapping activities of several agencies. The area of Foreign Affairs contains prime examples: six major agencies are involved in foreign affairs programs, each conducting its own planning without any systematic means of comparison among agencies.[15]

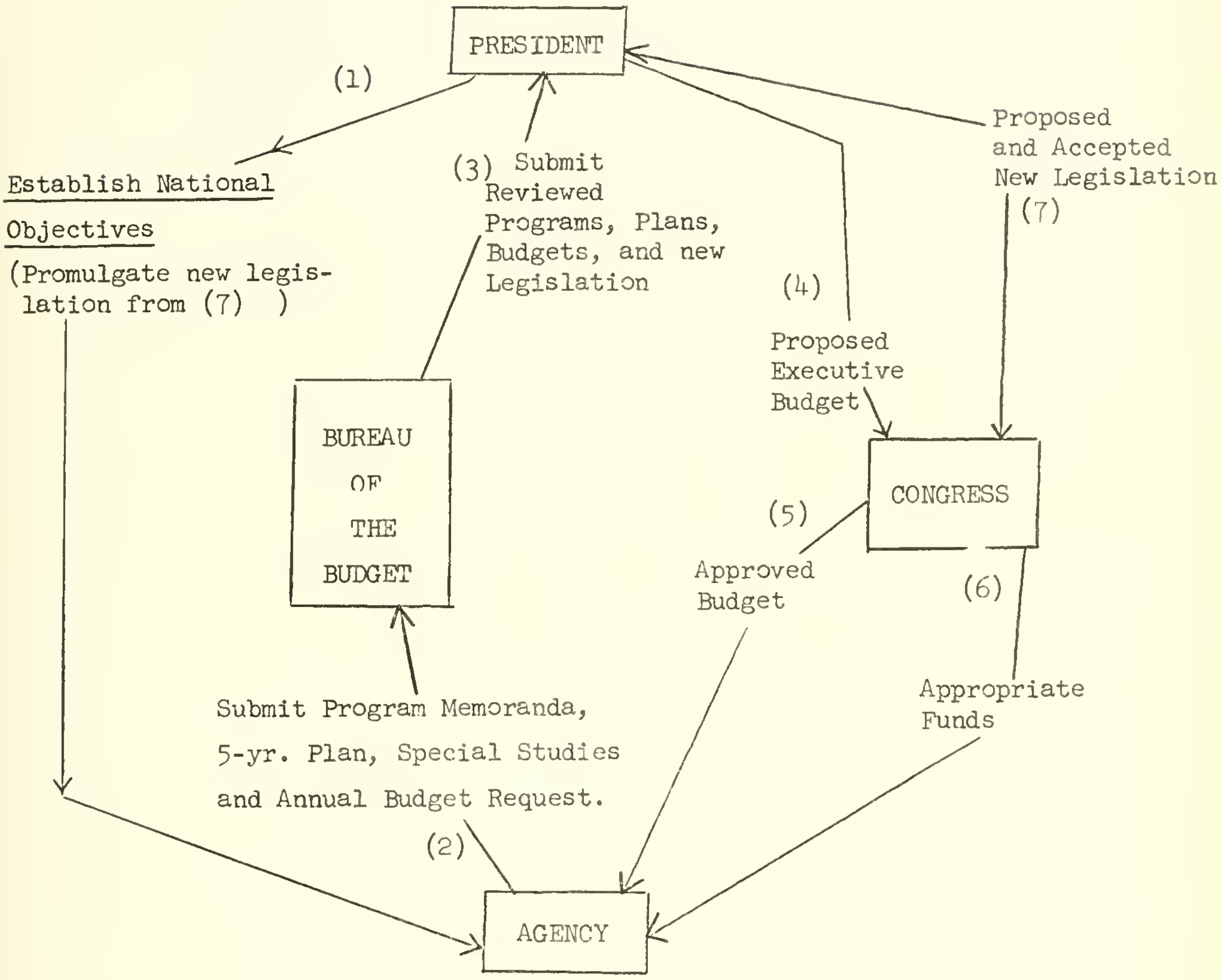
Nevertheless, some progress has been made in implementing PPBS, even

---

[14] Ibid.

[15] C.J. Schultze, Hearings Before the Senate Subcommittee on National Security and International Operations, August 23, 1967.

PPBS CYCLE


PRESIDENT
(1)
Establish National Objectives
(Promulgate new legislation from (7))
(3) Submit Reviewed Programs, Plans, Budgets, and new Legislation
BUREAU OF THE BUDGET
Submit Program Memoranda, 5-yr. Plan, Special Studies and Annual Budget Request.
(2)
AGENCY
(4)
Proposed Executive Budget
CONGRESS
(5)
Approved Budget
(6)
Appropriate Funds
Proposed and Accepted New Legislation
(7)

Note: Numbers beside each flow arrow indicate the sequence of steps

Figure III

in foreign affairs. Program categories have been designated encompassing the activities of all agencies within each of the 119 countries diplomatically recognized by the United States. Each agency submits its Program Memorandum to the U.S. Ambassador who then prepares a country Memorandum; these are reviewed by regional bureaus in the State Department -- at best, through comparison of benefit-cost ratios, at worst by allocation of dollar quotas to regions as in the past. Conformance has been spotty; the detailed Special Studies have centered on costs without going to measures of benefits, given the obvious difficulties in measuring the returns from diplomacy; as a result, comparisons of B/C ratios across countries have been rarely possible.

Some progress has been made in the Geological Survey. Major programs and sub-programs have been defined for the Department of the Interior, the Survey's parent organization. However, the problems of comparison of benefits from alternative programs exist here, too. They are increased by the diversity of Geologic Survey programs: the mapping of mineral resources falls under the generic program category of "Resource Management" in the Department of the Interior, while its engineering mapping activities in urban areas would appear to belong in "Improved Land Use for Suitable Community Environment", in the Department of Housing and Urban Development. Geological Survey goals have yet to be formulated in any economically operational manner.

The Geological Survey and Its Current Plan

The United States Geological Survey was established as an agency of the Department of the Interior in 1879. Its earliest responsibility involved producing topographical and geological maps related to investigation of natural resources (timber, water, minerals, soil), especially in the West. Maps at varying scales and range of detail continue to be the primary output of the Survey. The agency's functional responsibilities, however, have increased considerably over the eighty-eight years since its founding. The present organization of the agency, depicted in Figure IV, reflects current program areas of importance.

The current activities of the Survey are in keeping with a long-range plan developed in 1964. The time span of the plan ranges from a minimum of five years for some functions to twenty or more for others. Over the decade ending in 1973 it was planned to increase program levels in all areas. Total employment was to be increased by some 60 percent, from approximately 6,000 in 1963 to more than 10,000 in 1973. The approximate distribution of personnel employed in the various activities of the Survey in 1963 was: Topographical Division, 34%; Geologic Division, 16%; Water Resources Division, 35%; Conservation Division, 7%; Publications Division, Administrative Division, and other activities, 8%. These percentages were to remain relatively unchanged throughout the decade. Field reports were forecast to increase from 600 in 1964 to 1,000 in 1973 and maps from 4,900 to 10,000 over the same period. The Survey distributed 5.7 million copies of maps and reports in 1963 and anticipated an increase to 8.8 million copies in 1973.

United States Geological Survey

OFFICE OF THE DIRECTOR

Provides overall supervision and direction to programs which have as their principal objective the determination and appraisal of the Nation's mineral and water resources, the delineation of the physical features of the Nation, and the supervision of leasing of minerals on Federal and Indian lands.

Topographic Division -

Maps the physical features of the Nation.

Geologic Division -

Maps the geology of the Nation and appraises its mineral, fuel, and land resources.

Water Resources Division - Appraises the Nation's water resources and does related research.

Conservation Division -

Classifies the Federal lands as to water-power and mineral values and supervises the development and production of such minerals under appropriate leases.

Marine Research

Publications Division

Provides editorial review of scientific and technical manuscripts, and is responsible for the preparation of technical illustrations and for the reproduction and distribution of Survey maps.

Administrative Division

Provides budget, finance, property management, personnel, organization and methods, systems development, information storage and retrieval, and electronic computations and data processing services to the Survey.

Source: U.S. Geological Survey Long-Range Plan, 1964, p. 5, Figure 1.

Figure IV

The Topographical Division's plans were to complete maps of the entire United States at a detailed scale (approximately one mile per inch) by 1981, in addition to various special maps at other scales in response to specific needs as they arose. Examples of the special purpose maps are those of national parks, maps of the United States emphasizing specific features such as woodlands, and large scale, topographical maps of metropolitan areas. Topographical maps deal only with the physical features on the earth's surface, as distinguished from geologic maps which deal also with sub-surface structure. For this reason topographical mapping is relatively simpler, less expensive, and more rapidly done.

The Water Resources Division concentrates on basic research in watersheds and on prediction of future water resources. Its responsibility is to provide research findings on which other agencies rely for planning of major dam construction, irrigation projects, etc. The increase in activity planned for the decade 1964-1973 was based on a predicted doubling in water usage over the remainder of the twentieth century. In addition to studies of inland water resources, this division is engaged jointly with the Geologic Division in research of marine areas along the North American continental shelf and other contiguous ocean areas.

The Conservation Division's responsibilities, unlike those of the other functional divisions, are in the nature of control of oil, gas, mineral, and water resources rather than exploratory research. As with the Water Resources Division, the long-range plan called for increases in activity levels of this division to meet projected increases in usage of the resources for which it has responsibility. Its work is primarily inspection

and supervision of drilling and mining operations within government-owned lands.

The Geologic Division's activities are divided among four areas, corresponding to sections in its organization: Regional Geology, Economic Geology, Engineering Geology, and Experimental Geology. This division is the one studied in this paper, so its part of the long range plan is presented here in more detail than for the other divisions. Table V shows the proportion of activity and forecasts of increases in the four areas, in terms of man years.

Table V

GEOLOGIC DIVISION ACTIVITY LEVELS IN MAN-YEARS PER YEAR

	1964	%	1973	%
Regional (minerals) Geology	380	40%	720	41%
Engineering Geology	190	20	260	15
Economic (minerals) Geology	240	25	380	22
Experimental Geology	140	15	390	22
Total	950	100%	1,750	100%

Funding requirements for the division were forecast as increasing almost three-fold over the decade, from $16 million in 1964 to $45 million in 1973.

The largest of the four areas in terms of manpower and funding is Regional Geology. Its part of the plan involves geologic mapping of the entire United States on a sufficiently detailed scale (one-half mile or one

mile per inch) to provide the basis for development of all mineral and other natural resources in the country. In 1964 approximately 17% of the nation was mapped at these scales. The planned increase in activity would add some 2% annually, the entire nation being covered by the year 2000.

The area of Economic Geology is devoted to the location and detailed reporting of deposits of high-value minerals and fuels. Unlike Regional Geology it is a commodity-oriented rather than an area-oriented program whose projects would more often involve in-depth studies of exploitation on a national scale as well as mapping location studies. The long-range plan projected a 75% increase in level of activity during the decade 1964-1973 to meet expanding government and industry needs for minerals and fuels. A specific component of Economic Geology, the heavy metals program, has assumed increased importance recently in the search for additional gold deposits in the light of U.S. balance of payments difficulties.

Engineering Geology includes producing maps useful for highway and building construction and urban development. Other government agencies such as the Atomic Energy Commission (nuclear test-site exploration) are important users. In 1963 twelve urban areas were in various stages of being mapped, with eight more to be added by 1968. The study and prediction of geologic hazards occurrence such as volcanoes and earthquakes is also conducted by this section in conjunction with Experimental Geology. Expansion of Engineering Geology programs during the ten-year planning period was projected at about a 50% increase (primarily in the activities sponsored by other agencies).

Experimental Geology involves basic research in natural rock-forming

processes based on geochemistry, petrology, mineralogy, biogeochemistry and geophysics. Because of the unpredictable nature of such research, the long-range plan is less specific as to future objectives. An 180% increase in level of activity was projected for the decade 1964-1973.

The 1964 Geological Survey Plan as a PPBS Program Memorandum

Although the long-range plan projects activities of the Survey over an extended period of time, it does not fulfill the requirements for a Program and Financial Plan within the PPBS framework. At least two critical components are lacking: formulation of meaningful sub-objectives and economic comparison of programs and elements or projects within programs.

The plan defines agency sub-objectives "...which have evolved from the Geological Survey's original charter: to determine and evaluate the quantity, quality, and distribution of the mineral and water resources of the United States; to provide topographical map coverage of these areas at scales adequate for modern needs; to classify the public lands as to their mineral character and water potential; and to supervise oil, gas, and mining leases on public lands."[16] As formulated these sub-objectives do not lend themselves to program design and evaluation; they are qualitative descriptions of programs rather than goals or targets. This follows in part from lack of appropriate definitions of relevant national objectives by the Executive Office and Congress. The Survey has proceeded over the years to redefine and rejustify

---

[16] U.S. Geological Survey Long-Range Plan, 1964, p. 2

its own programs and activities without meaningful guidance from higher levels.

The result is an inability to analyze and compare alternative activities. Within the Geologic Division, for example, no comparison has ever been made of the relative social benefit of mapping in urban areas, a component of engineering geology, and general regional mapping.

Thus, the Survey's activities are in pursuit of broad goals historically set, and its activities are carried as far as possible within budget limitations. The current long-range plan does not project any curtailment of programs in any area. Apparently, the growth rates of some programs are to exceed others principally because of more interest in the Survey in these programs. At the lowest levels the primary criteria for deciding what areas to map at what scale are the availability of knowledgeable professional manpower and the interests of individual geologists. Such criteria are some distance removed from a measure of the value or net benefits to the nation of mapping one area rather than another.

What follows is a first attempt to do a Program Memorandum for the Geologic Division of the Survey as a prototype study. The problems of subobjective definition and program element comparison are directly addressed. The over-all objective is seen as one of providing all geologic information which has net national value -- that is, where unit benefits exceed unit costs -- and which can not be provided less expensively by the private sector or by other government agencies. The Program Memorandum is followed by a "special study" proposing a system or organizational structure which would be appropriate for the implementation of PPBS in the Geologic Division.

A Program Memorandum on Regional and Engineering Mapping

The measurement of social benefits due to the mineral mapping activities of the Geological Survey provides a useful example of how such measurements might be made given an extreme scarcity of information. Ideally we would develop the demand function for all users of regional geologic field information as $P = f(Q, q, \alpha)$ with P equal to the dollar value at the margin for Q volume of services, given q volume of related and competing services and α as a quality index of this service. The "social benefits" of a given level of output -- in this case, of maps providing information of certain quality and coverage -- is then the sum of all P from Q = 0 to q equal to the level of information provided. For year t, benefits $B_t = \int_0^q f(Q, q, \alpha)dq$ and the total benefits over all years equal $B = \sum_t B_t/(1 + r)^t$. Knowing the costs $C = \sum_t C_t/(1 + r)^t$ to the Survey of the regional mapping program, we could calculate a benefit-cost ratio for these services. But it is not possible at this time to obtain the data required to construct demand functions at useful levels of accuracy. We have to resort to more limited but manipulative approaches to benefits. The first approach is from the status quo. The Survey has produced minerals maps of standardized quality at a steady rate over the last 25 years, and has built a clientele for these maps. They are relied on and provide "value" or "utility" to fuels and minerals exploration companies in the case of "minerals maps". The first objective might be to choose program size and mix that makes this "utility" as great as possible.

Regional maps provide basic information at the first stage of the decision on whether to undertake exploratory mining or drilling operations.

In the absence of USGS regional maps, companies invest in geologic reconnaissance and field research to obtain "Stage I" information on the general characteristics of substrata formations -- on whether there are mineral resources of the type sought at some location. If the Stage I information is positive, detailed mapping and exploration of the most promising areas is undertaken to provide information for the "Stage II" decision on the erection of facilities. "Stage II" information differentiates among resource deposits for those for *economic* extraction (given relevant levels of extraction costs). The plan to maximize the net benefits of the regional maps can be given form by finding which of three alternatives is the best: (1) reduced mapping activities (2) the present level of mapping (3) expanded mapping activities. Consider first the benefit/cost ratio of moving from (2) to (3), and second the ratio of moving back from (1) to (2).

If current USGS regional maps were available for all parts of the United States there would be no reason for private companies to undertake Stage I activities. In practice, *Stage I expenditures of private companies beyond the areas now mapped by the Survey must be less than or equal to the value of implicit benefits to private industry of these activities.*[17] An extension of USGS regional mapping to those areas considered promising by

---

[17] That is, the B/C ratio of private companies during Stage I mapping must be greater than or equal to one if private investment is efficient. Then $B^* \geq C^*$ for private benefits B^* and costs C^*; the rates C^*/C for government costs C is less than $B/C = B^*/C$ where B/C is the Survey's benefit/cost ratio.

industry would produce social benefits at least equal to present private Stage I expenditures in these new areas. Then benefits may be calculated from available data as:

$$B_t = N \times P \times G$$

where

B_t = total benefits from an increase in USGS regional mapping, in dollars in year t;

N = number of geologists employed by private industries for Stage I and Stage II work;

P = percentage of these geologists engaged in Stage I work

G = average expenditure per geologist, including supporting equipment.

Estimates for N, P, G have been obtained from preliminary surveys of firms and from data on file with the American Geologists' Institute. We have compiled these as our best estimates as follows: N = 300 to 500 (based on data from AGI); G = $90,000 to $100,000 per year (the range of figures quoted by a number of industry geologists in telephone interviews); P = 0.10 to 0.50 with a most likely value between 0.10 and 0.20 (also from telephone surveys of selected industries). Utilizing these values in the calculation of the benefits, B, we obtain:

B_t = (300)(100,000)(0.15) = $5,700,000 per year t, and the upper and lower bounds for B_t are:

Upper: B_t = (500)(100,000)(0.20) = $10,000,000 per year

Lower: B_t = (300)(90,000)(0.10) = $2,700,000 per year

as the range of estimates of benefits from increasing the Survey program to cover all of the areas of interest to the minerals industries.

On the cost side, we are interested in an annualized cost to the USGS for mapping those areas where private companies are investing in Stage I work. We assume these to be unmapped areas with some potential for profitable exploitation. The cost is $C_t = \frac{A \times K}{L}$ where C_t = annualized cost, \$/yr.; A = potentially profitable unmapped area, sq. miles; K = cost per square mile of USGS regional mapping activity; L = the time duration or lifetime of a regional mapping program, in years.

Estimates for A, K, L were compiled from examination of Survey work in areas close to the private Stage I work, from Survey geologists' personal estimates, and from telephone interviews with company geologists in the ferrous and heavy metals industries. The unmapped area seems to be 700 quadrangles of 250 square miles each. The mapping costs vary greatly for widely differing terrains but average to \$500 per square mile. The map should take from three to five years to complete under normal conditions; given the magnitude of the expanded program, the most optimistic target would be completion of all 700 areas in a five year plan. Inserting these figures into the cost formula gives $C_t = (175{,}000)(500)/5 = \$17{,}500{,}000$ per year. Assuming that the mapping remaining to be done is in good part that at inaccessible locations, the costs per square mile are closer to \$700 and total annual costs are $C_t = (175{,}000)(\$700)/5 = \$24{,}500{,}000$ per year. In contrast, the USGS estimate of potential resource areas may well be high and in reality they might have to map only one hundred thousand (100,000) square miles; then the costs are $C_1 = (100{,}000)(\$500)/5 = \$10{,}000{,}000$ per year.

Utilizing the benefit estimates calculated in the first part of this section and the above cost estimates, benefit-cost ratios can be obtained.

Total benefits are $\sum_t B_t/(1 + r)^t$ for the lifetime of the maps. Given the present rate of advance in interpretation of geological field samples, the typical period before obsolescence is now twenty-five years. The rate of discount "r" of future benefits is that applying to the users of the Survey's results; it is assumed here to be in the neighborhood of 20 per cent since the users are exploration and development companies (with large variations in profits on returns but low tax levies on these returns). Total costs are $\sum_t C_t/(1 + r)^t$ for the five years it takes to complete the saturation mapping program. Then the ratios are:

B/C (expected) = ($28,200,000)/($52,300,000) = 0.54

B/C (high) = ($49,500,000)/($29,900,000) = 1.65

B/C (low) = ($13,300,000)/$73,200,000) = 0.18

and the most probable range for this ratio is:

B/C (low & low) = ($13,300,000)/($29,900,000) = 0.44

B/C (high & high) = ($49,500,000)/($73,200,000) = 0.67, given that high private expenditures ("benefits") are caused by the same conditions as high Survey expenditures. This leads to the conclusion that the benefit-cost ratio for an extension of the Geologic Survey's minerals mapping activities lies between 0.44 and 0.67.

An extension of these Survey activities would not seem consistent with the basic objectives of maximizing net users' benefits. This is subject to considerable uncertainty because of the scant data underlying these estimates. If anything, the calculations probably underestimate the real ratio, since they do not include the benefits to all users of the maps produced by this hypothetical increased program. In particular, such users might

include state governments, construction companies or educational institutions not directly involved in mineral exploration for commercial extraction. Correction for this bias could be made with more reliable data; we recommend that efforts be made to construct a larger sample of users and that the analysis be started again with more complete information.

The second alternative to the present program is to reduce this activity to a more modest level. The benefits from the stock of current USGS regional maps are the foregone costs to private companies from having to replicate the field research themselves. These benefits are hypothetical -- there is no way to measure the amount that the companies would have spent in the absence of this Survey expenditure. But their lower bound can be estimated from the expenditures companies make in obtaining detailed geologic or Stage II information once they have the Survey maps available and utilize them. We may assume that a firm will invest in Stage II work up to the point at which a forecast can be made that the area will or will not yield some net profits from sub-surface exploitation. The value to the exploration company from the maps are these forecast net profits (equal to "B"); they should equal or exceed the costs of both Stage I mapping (equal to C_I, as incurred by the USGS) where the company pays for these costs in charges for the resulting maps and the costs of Stage II exploration (equal to C_{II}, as incurred by each company). The total benefits from the maps are $B \geq C_I + C_{II}$ summed over all firms, and the benefit-cost ratio of Survey work $B/C_I \geq (C_{II}/C_I) + 1$. Where the Geological Survey costs are not passed on to the map users -- in the extreme case, where map prices are zero -- then Stage II work will be carried to the point of $B \geq C_{II}$ and the benefit-cost ratios $B/C_I \geq C_{II}/C_I$.

Thus, before the fact the maps are worth at least what the companies spend on Stage II work, since no company would spend more than the benefits derivable from exploitation of resources shown on these maps.

The calculation of these benefits is given by the reduction in Stage II expenditures corresponding to a reduction in current USGS regional mapping activity by some arbitrary amount:

$$B = R \times P' \times (1-P) \times N \times G$$

where

B = benefits equal to the reduction in Stage II expenditures, \$/yr.;

R = percentage reduction in USGS regional mapping activity;

P' = percentage of Stage II expenditures incurred in areas where USGS regional maps exist;

and P, N, G are as defined above. Setting R at 10 per cent, P' at 80 per cent -- in keeping with the value of P estimated above -- and substituting the figures estimated above for P, N, G gives

$$B = .10 \times .80 \times (1 - .15) \times 400 \times 95{,}000 = \$2{,}580{,}000 \text{ per year.}$$

On the cost side, the existing stock of regional maps was estimated to be at about 3,000, half of which cover areas of potential economic benefit to the extractive industries. The stock is increasing at four per cent per year. Consequently, a 10 per cent reduction in the current regional mapping program would correspond to six fewer maps each year of special value to the mineral industries. Each map covers a 15-minute quadrangle, containing an average of 250 square miles, and has a unit production cost of \$500 per square mile. Using the same cost formula, $C_I = \frac{n \times A \times K}{L}$ where n = number of

quadrangles and A, K, L are as previously defined, the following estimate is obtained:

$$C_I = (6 \times 250 \times 500)/1 = \$750{,}000 \text{ per year}$$

This represents the annualized cost reduction to the USGS. The benefit-cost ratio for not reducing the activities of the Survey is thus

$B_{II}/C_I = \frac{2{,}580{,}000}{750{,}000} = 3.4$ (or $3.4 + 1 = 4.4$ given full payment for the costs of Survey mapping) and the range calculated using the limits of the estimates of the variables above is from 2.4 to 5.5

These benefit-cost calculations for changes at the margin for regional mapping activities show what one would expect from a first experiment. There is wide variation in estimates of B/C as a result of small changes in the few statistics available. But they all show that benefits from continuing at the present level of activity are far greater than those from expanding the activity, and that any significant expansion of the present program in minerals mapping shows possible benefit/cost ratios that fall short of 1.0 by a substantial margin. But they are presented only to illustrate a promising means for the use of readily available information. Useful benefit-cost ratios for changes at the margin in these activities can be obtained if values for the variables in preceding equations are obtained through systematic surveys.

Would the benefits of more regional mapping exceed those lost from less engineering mapping? Perhaps the opposite is the case: a reallocation of geological field personnel from mineral to engineering mapping would lead to greater returns from resources used.

The objective of the engineering geology program is to provide informa-

tion for local governments in construction and urban planning programs, and for private companies in carrying out construction programs. The activities in the program provide data on: 1) sources of construction material such as sand and gravel 2) foundation and excavation conditions for use in locating skyscraper, reservoir, or other heavy construction sites and 3) erosion, weathering and landslide conditions which affect the stability of land utilization.

This information is provided in 7.5 degree mineral geologic and sufficial maps (drawn at a scale of .16 square miles per square inch), formal reports accompanying the maps, and informal consulting by Survey field researchers with agencies desiring information. The mapping is often carried out with the participation of geologists from local governments, with the Survey training local participants in the use and interpretation of the geologic maps.

In most parts of the country there are county or city engineering departments which are responsible for formulating regulations for the safe development of public and private lands. The maps and information provided by the USGS enable such departments to provide resource zoning information and routings for highways, utilities, and sewage lines. In those areas where such staffs exist, the number of geologists is too small to perform this basic mapping; instead, the departments rely on the USGS or outside consulting firms for the geologic data. The maps provided by the USGS are used to locate sand and gravel deposits and geologic faults, and are supplemented by further intensive mapping to establish specific building sites. This additional exploration is usually performed by local government geologists or private developers, but the areas for further exploration are determined by the USGS maps and the

accompanying reports.

The question is how to provide dollar measures of value of the knowledge embodied in the maps. In several interviews, county engineers were asked to describe the use of all types of geologic maps and to make qualitative comparisons of USGS maps with maps provided by private consultants. In the case of those produced by private consultants, there was often a question regarding the methodology used to obtain the information, whereas the USGS standard procedures for their data collection were not questioned. USGS maps and reports contain exhaustive information -- as exhaustive as the science allows -- about the geologic formations and structures in the area, whereas other reports based on soil sampling procedures do not provide direct information for strata below ground level. In addition, USGS maps are publicly available. Consultant maps and reports are usually confidential and available only to the requesting party. Hence, there is extensive duplication of work when only consultants are used to perform the survey.

Comparison of three different sources of geologic information used in the zoning of sand and gravel resources in three counties in the Greater Washington area is presently underway in the USGS. In the first area, no survey was made. The community was zoned strictly on the basis of the intuition of the town planning board. Several years later, in a USGS study, extensive sand and gravel deposits were discovered in several areas which had been zoned strictly for residential use and had subsequently been developed for this use. The information was too late to lead to utilization of these resources in any additional construction in the community, since houses had been built on the best deposits. In the second area, a private consultant

was engaged by the planning board before any zoning or substantial building had been performed. On the basis of soil analysis, the county was zoned. The consultant's estimates of the sand and gravel reserves at the sites examined were in excess of the actual supply. Those areas of potential reserves considered to be "excess" were zoned for residential use once again -- and then, when in demand for their sand and gravel content, could not be rezoned. These mistakes made it necessary for construction firms to transport gravel across the county which increased construction costs. In the third case, the county had recent USGS geologic maps available and was able to reroute a major highway construction project to take advantage of a gravel bed which ran nearly parallel to the new route but was far removed from the old route.

The general effects of using USGS versus private maps -- or no knowledge at all -- are apparent from these extreme cases even though no estimate of cost savings has been made. There are several other instances reported in which similar situations have occurred. There are clearly several dimensions to the benefits associated with the USGS engineering maps: 1) uniformity and accuracy of detail, 2) the nature of the information reported, and 3) the public reporting of the results. The first two, however, can only be estimated qualitatively at present and as such are not a good basis for quantitative benefit analysis. Only the third can be measured, in terms of the costs of the duplication incurred when all mapping in an area is performed by private consultants.

The benefits resulting from the reduction in duplicative efforts are the total dollar costs incurred by the second through the nth consultant

providing information in place of USGS maps and reports. They can be computed as follows:

$$B = (M)x(C)x(D)$$

where B is the total expenditure per square mile for private mapping; M is the number of man-days required to prepare the map and report; C is the average per diem consulting fee, including equipment costs; and D is a measure of the duplicative effort - equal to the number of times in which the same area is mapped by consultants for different users.

Estimates of the values for each of the variables were obtained from private consultants. The ranges on these numbers can be used to compute upper and lower bounds on the value of B.

M: 5 to 8 depending on the area and the amount of core field drilling required to obtain the desired geologic data.

C: $500 to $700, of which $300 is the consultant's fee and the rest is based on the amount of drilling performed at $10 per foot.

D: 3 to 6 depending on the region being mapped.[18]

Using these values for M, C, and D, the values for B are:

$$B\ (\text{upper}) = (8) \times (700) \times (6) = \$33,600 \text{ per square mile,}$$

$$B\ (\text{lower}) = (5) \times (500) \times (3) = \$7,500 \text{ per square mile.}$$

These estimates seem reasonable when compared to those used by consultants in determining their own charges (exclusive of the consideration for duplicative

---

[18] In several instances the estimates of duplicative efforts were even higher than 6. Most of those interviewed admitted that this was probably due to developmental rather than exploratory engineering drilling (where resources were known and were about to be utilized).

effort).

The benefits have to be compared with the costs of engineering field work at the Survey to replace the private activities. There are data available for FY1967 on the costs incurred by the USGS in performing engineering mapping, reporting, and informal consulting. They show that the present level of activity by the USGS in this area is quite small: of the 360 engineering geologists, over ninety percent have been on loan, full-time, to government agencies such as NASA, the AEC, and the DOD. In addition, most of the others have been involved in geologic hazards studies for a major portion of their time. In FY1967, only twenty geologists were engaged in the mapping, reporting and consulting, and the total work performed was equivalent to eight man-years of effort.

Two levels of activity can be costed, the first at the present level and the second at twice that level. By doubling the present rate it is possible to determine the effects of increasing the size of the program. (No attempt is made to analyze a smaller program since the present activity level is quite small relative to the amount of potential work in this area). There is excess demand at present rates which support the doubling of effort: the typical city or county survey comprises an area of 400 to 500 square miles, almost twice the total area mapped last year, and there are a large number of cities seeking these surveys.

To cost the two levels of output for comparison with benefits, consider

$$C = V + S/A$$

where C is the cost per square mile for the USGS to perform a project; V is the cost of mapping, report preparation, and consulting on a per square mile basis;

S is the total annual cost of support required for the library, laboratory, administrative, and other services; and A is the total annual area mapped in the engineering geology program.

To calculate V, it is necessary to multiply the annual cost per geologist (including equipment, office, and travel allowances), G, by the number of man years, Y, and divide this by the number of square miles last year, A. Therefore, the equation for V is

$$V = (G) \times (Y)/(A)$$

Estimates for G were obtained from several persons in the USGS and set at from $30,000 to $40,000 per man year. Values for the variables Y and A were taken from publicly available Survey data for 1967 as follows: Y is 8 man years, A is 286 square miles. The values obtained for upper and lower bounds on V are: $V(\text{upper}) = (40{,}000) \times (8)/(286) = \$1120$ per square mile, and $V(\text{lower}) = (30{,}000) \times (8)/(286) = \$840$ per square mile. The values of S, found in Survey budget statistics, vary from $300,000 to $400,000 per year. Substituting V, S, and A into the equation for C:

$$C\ (\text{upper}) = (1120) + (400{,}000)/(286) = \$2520 \text{ per square mile,}$$

$$C\ (\text{lower}) = (840) + (300{,}000)/(286) = \$1890 \text{ per square mile.}$$

An estimate of the cost of mapping per square mile was made, based on regional mapping costs, without knowledge of the above calculations, by a senior staff member of the USGS long concerned with engineering mapping. His figure was slightly above the lower estimate for C.

For the present program Benefit/Cost ratios are calculated by dividing B by C. The range of these ratios is:

B(upper)/C(lower) = (33600)/(1890) = 17.8

B(upper)/C(upper) = (33600)/(2520) = 13.3

B(lower)/C(lower) = (7500)/(1890) = 4.0

B(lower)/C(upper) = (7500)/(2520) = 3.0

The wide range is due to large differences in the estimates of the extent of duplication, and in the costs of work by consultants in the absence of USGS maps.

If the program were double its present size, the costs of V and S would be different from the estimates shown. The costs for V might decrease by as much as ten percent due to a more efficient scale of operation of the whole program. The total costs of support services S would increase, but not by a very great amount; the present utilization of laboratory and other support services is significantly less than their present capacity. It is expected then that S would not increase by more than twenty-five percent, if the present program were doubled. The values used for calculation of C (expanded) are: V(upper) of $1000 per square mile, V(lower) of $760 per square mile, S of $375,000 to $500,000, and A of 572 square miles. Corresponding values for C (expanded) are: C (expanded upper) = (1000) + (500,000)/(572) = $1875 per square mile, and C (expanded lower) = (760) + (375,000)/(572) = $1415 per square mile. From these costs, and from the same level of benefits as those in the present program, the benefit/cost ratios will be 33 percent greater than those in the present program. This is reasonable: excess demand at present program levels may indicate identical benefits from a larger program, and reduced costs follow from limited economies of scale.

As in the evaluation of minerals mapping, this is a first effort at

finding B/C ratios. The estimates vary widely. But once again a strong impression is derived from these ratios: they are all larger for engineering than for minerals mapping. Based on the average and the range of ratios, it appears that an increase in the size of the present engineering program is warrented even at the expense of a reduction in the size of the minerals program.

There is a third program which may merit transfer of funds from the other two. There are benefits of applied research in geologic hazards which may outweigh the costs by an even greater degree. We will estimate the benefits for that part of the program which has as its ultimate objective the control of earthquake damage in the United States.

The benefits are based on stages for reaching specific objectives:

Stage 1: Basic research to provide general knowledge in field (example: geophysics)

Stage 2: Applied research to prove the possibility of using knowledge to achieve a practical result (example: investigation of the effect of fluids in faults to pre-release rock forces before they build up to hazardous amounts and potential earthquake damage)

Stage 3: Development to prove economic feasibility and provide detailed technology (example: field tests of fluid earthquake prevention)

Stage 4: Capital expenditure for application using known technology (example: obtaining permanent supply of men, equipment necessary for large scale application of fluid method)

Stage 5: Continuous implementation and use of new method (example: use of method on a routine basis)

We shall assume that Stage 1 is complete or is being executed as part of the USGS basic research program. We combine Stages 3, 4 and 5 into a single cost estimate. The only possible procedure for estimating benefits of the USGS

program, which represents Stage 2 work, is to allocate the total benefits to the individual stages in proportion to their costs. If B = total benefits, and C_1, C_2, C_3 = costs of Stages 1, 2 and 3 (where C_3 lumps together Stages 3, 4, and 5) then $C = C_1 + C_2 + C_3$ and $B_1 = \frac{C_1}{C} B$, $B_2 = \frac{C_2}{C} B$, $B_3 = \frac{C_3}{C} B$. [But since $B_2 = (\frac{C_2}{C}) \cdot B$, the benefit-cost ratio for Stage 2 is $B_2/C_2 = [B \cdot (\frac{C_2}{C}) \cdot \frac{1}{C_2})]$, = B/C. Consequently, the ratio for Stage 2 is in reality no more than an overall ratio for the entire program].

The first step in the analysis is to estimate the benefits B and the costs C_1, C_2, and C_3 of the various stages. Total benefits are the cost savings from preventing earthquakes, or from moving property in time to prevent its destruction before earthquakes take place. The following tabulation shows the results in property damage from not doing this:

U.S. Major Earthquake Damage, 1956-1966

Date	Location and Description	Public and Private Property Damage
Mar. 1957	Aleutian Islands causes tidal wave damage in Hawaii	$1,000,000
Mar. 1957	San Francisco	$1,000,000
Aug. 1959	Yellowstone Nat'l. Park	--
Apr. 1961	California	$5,000,000
Mar. 1964	Alaska	$750,000,000
Apr. 1965	Seattle	$15,000,000
June 1965	California (landslide)	$7,000,000
	Total	$774,000,000

Source: Compiled from the New York Times.

The benefits might be these costs foregone. Since 1956 to 1966 was a period of unusually high earthquake activity, we may take $50,000,000/year in property damage as a reasonable estimate of gross benefits.[19] Assuming implementation costs -- the program expenditures C_5 make an area "Earthquake-proof" -- of no less than $20,000,000/year, we have net benefits of successful earthquake control of $30,000,000/year. Using an 8 percent discount rate, this amounts to a capitalized present value of $375,000,000.

We now estimate the costs C_1, C_2 and C_3. Each of the anticipated expenditures for research does not automatically achieve a definite result: research is risky and to reflect this we can assume a probability of successfully achieving the objective of no more than 0.50. Using USGS figures for basic research, we estimate that the relevant portion of expenditures has been or will be $1,000,000/year for 5 years, or a total cost (C_1) of $5,000,000.[20] Applied research expenditures for such a program could easily average $1,000,000/year for 10 years with a present value (C_2) of $6.7 million. Development costs are extremely speculative; we estimate a total present value (C_3) of $30,000,000 to be in the correct range.

The expected benefit of the earthquake program is simply (.5)(benefits of successful program) = $187,500,000. Since this would not occur until after the 10-year applied research program, we must further discount these benefits. Using the 8% rate as before, the present value of the benefits is B = $87,000,000.

Now the total cost $C = C_1 + C_2 + C_3$ of the three stages is

---

[19] We ignore loss of life, which is relatively small in most cases.

[20] This is not discounted because some work has already been done and most of the remaining will be done in the near future.

(\$5,000,000) + (\$6,700,000) + (\$30,000,000) = \$41,700,000. Consequently, the benefit-cost ratio B/C is just 87/41.7 = 2.1. This highest conceivable ratio of benefits to costs -- giving the doubt in every case to a "high" or "optimistic" forecast of net results from research -- is too low to compete for resources with the mineral or engineering mapping programs.

This first attempt to select the most efficient program elements has been extremely cursory. There is currently no basis for re-allocating resources from other agencies and channeling them to the Survey, nor is there reason for giving some USGS resources to programs with alternative objectives. The estimates of benefits from these and alternative programs are not sufficient to provide a rationale for such tradeoffs. But some judgments can be made as to the best uses for the personnel and capital now installed in the USGS: there should be more emphasis on engineering mapping, perhaps at the expense of minerals mapping and certainly at the expense of geologic hazards research.

The Stage Beyond the Program Memorandum:

An Organizational Framework for PPBS in the Geologic Survey

Effective implementation of PPBS in the Geologic Survey will require changes in the organizational structure of the agency itself. The recommendations here for such changes are designed to enable the Geologic Survey to maintain its professional scientific atmosphere; however, several concessions must be made if conformance to PPBS is to be achieved. To show this, we describe first the management planning and control system for PPBS and briefly outline the organizational changes we envision to put this system in the

Geological Survey.

Currently, each of the four sections of the Geologic Division (Regional Geology, Economic Geology, Engineering Geology and Experimental Geology) is under the direction of an Assistant Chief Geologist who reports directly to the Chief Geologist. Within each section there is a further breakdown into "branches", each with a Branch Chief. For example, the branches included in Economic Geology are Base and Ferrous Metals, Light Metals and Industrial Minerals, Organic Fuels, Radioactive Materials, and many others. In Regional Geology, branches follow geographic breakdowns: New England, Eastern States, Northern Rocky Mountains, and so forth. Thus, the criteria used for redefining these subdivisions are varied, some being functional, others geographical and user-oriented. The user-oriented criteria specifically apply, for example, to the military and NASA projects performed by the Geological Survey acting as consultants on a "Pay-Back" basis.

The existing organizational structure presents two problems for implementation of a PPBS framework by the agency. These are the difficulties of (1) defining independent or mutually exclusive programs for achieving specified objectives, and (2) allocating and coordinating professional personnel to selected programs.

There is considerable interdependence and overlap of objectives and programs in the four areas, making it infeasible to define these specialties as programs in the PPBS sense. For example, the activities and output of Regional Mapping not only provide inputs for other sections but also utilize common resources in varying degrees. In the light of these interdependencies detailed and on-going benefit-cost analyses can be properly performed only if

transfer prices for resources and transfer benefits for outputs are determined. This would be difficult -- perhaps more difficult than re-organization of the agency to coordinate the interdependency problems.

As we have indicated, geologists working in the Survey have great freedom in selecting sites for mapping and exploration. The professional field geologist prepares and submits his proposal for preferred activity to his Branch Chief. One of the officials at the Geologic Survey described this situation as follows:

> If he can convince his Branch Chief that the project is good on its own merits, he will map it. His interests then determine what areas will be mapped. There is no planning to decide whether or not to work a given area. Each project is evaluated on its own merits, and there is no comparison across projects. If a project looks good by itself, it gets done.

At worst, it is conceivable that geologists from different specialties could map the same area, although the relevant content of the final product (map and report) could well differ. While this is hardly likely, the fact remains that the locations of greatest research interest to a geologist -- full of exotic strata -- may not be of greatest interest to final users of resources. Coordination and collaboration on a particular mapping project should lead to reductions of redundant or economically uninteresting geologic information.

Implementation of PPBS by the Geologic Division will require some alteration in the current academic and professional philosophy which permeates the organization. We do not feel, however, that radical changes are necessary. To this end, we present an outline for organizational alterations that should be of assistance in adopting PPBS.

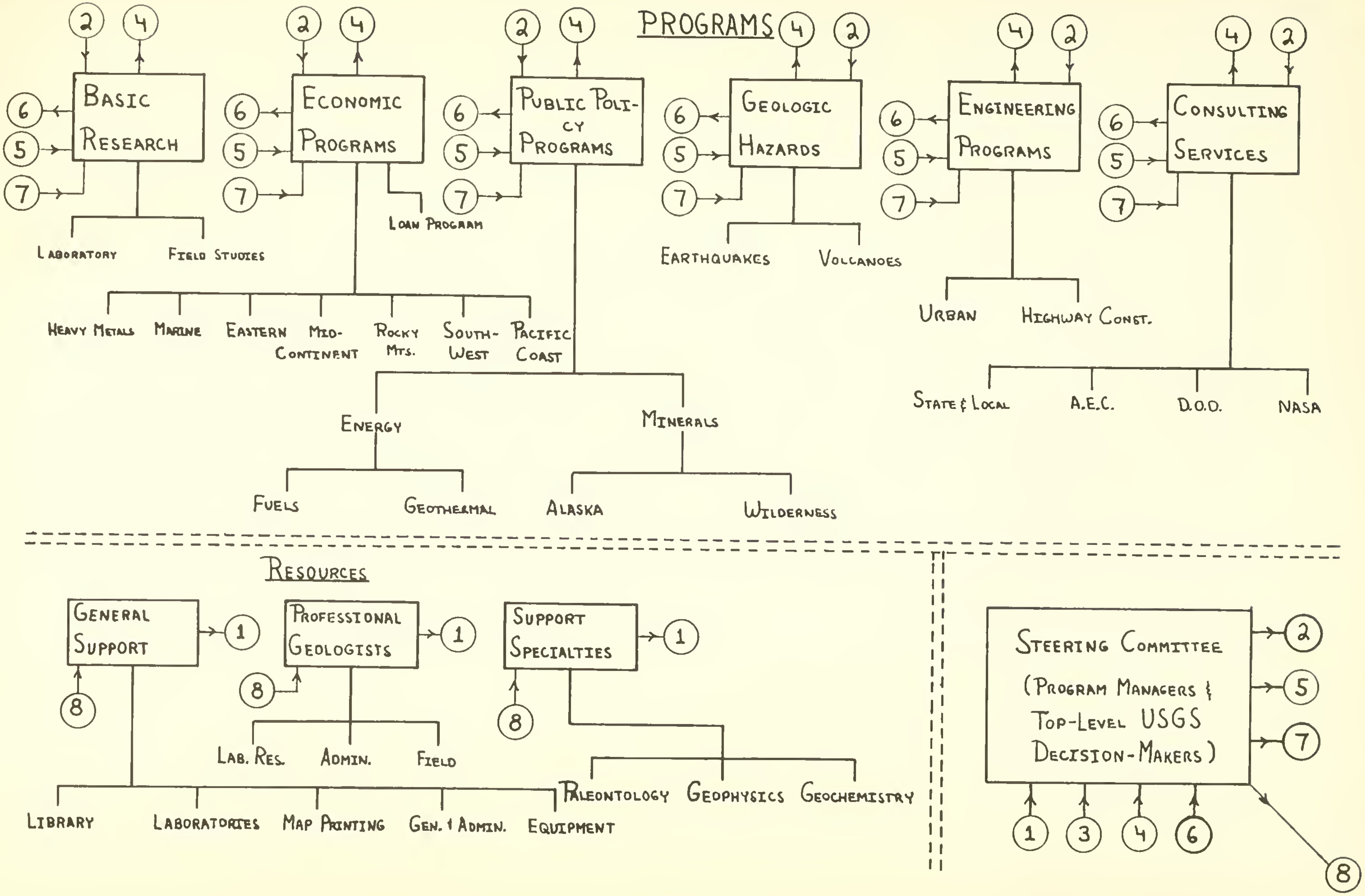
Programs may be defined operationally as collections of resources, organized and operated independently. Figure V provides a listing of six major programs delineated from current and potential work by the Geologic Division. These are:

(1) Basic Research - This program provides information about the earth environment. Uses for the information are varied, ranging from a satisfaction of intellectual curiosity to suggestions for solutions to problems not included in the research design. The benefits of this program are extremely difficult to measure, both because of the nature of the research process and the fact that research knowledge is a "free good". Benefits might be defined in terms of changes in long run technology and economic growth, and discounted at some long run social rate of interest.

(2) An Economic Program - This program provides information for the exploitation of natural resources. The information generated is used directly, for example, by the minerals and fuels industries in exploration activities. A first attempt at benefit estimation for these programs was made in the preceding section; second attempts require collection of detailed demand data by the geologists working in the area.

(3) A Public Policy Program - The information generated here is primarily used for governmental decision-making. Elements of this program include current projects labeled "Wilderness" and "Alaska", and collection of basic data on energy sources such as fuels and geothermal for long range economic planning. The Wilderness program provides an informative example of the impact geological information may have upon policy decisions. Information provided by the Survey will enable the Federal Government to determine which lands should be

Figure V: Program and Resource Structure



established as National Parks and which should remain available for economic exploitation. To adequately measure the benefits of the program, it would be necessary to know not only what decisions would have been made without the availability of the information, but the relative social value of the alternatives involved. As in basic research, the benefit measurement is difficult and can only be accomplished by establishing a capability for demand analysis among the people in the program.

(4) Geologic Hazards - This program provides information on such things as volcanic activity and earthquakes, and yields information useful in the construction of urban areas in safe zones. Benefit estimation for this program has been outlined above.

(5) Engineering Program - As previously described, this program provides engineering information for such uses as urban and highway construction. The information is of assistance to cities in planning sewerage facilities, subway systems, and excavations. First efforts at benefit estimation for this program have been described above.

(6) Consulting Services - These programs cover activities currently performed on a "payback" basis. Benefits may or may not be related to amounts paid for services rendered. There is some suspicion that intergovernmental transfer payments are not based on prices for services rendered, and thus are not measures of the dollar benefits of these services. The personnel in these programs will have to carry on research into the determinants of charges, and the final demands for the services of the agencies "buying" Survey services, before attempting to estimate benefits here.

We have separated these six programs primarily on the basis of

independence of end users of Geologic Division output. No attempt has been made to formulate sub-objectives for the Survey or the Division -- an exercise most essential to program area definition in PPBS. These six breakdowns are useful here in illustrating the succeeding steps of organizational design and establishment of control and procedural policies.

The first step in establishing control is the assignment of responsibility for planning and execution of these six programs to program managers. They could well be geologists who have a preference and capability for administration, and who will be responsible for defining and producing program elements. Next there should be a Steering Committee headed by the Chief Geologist of the Division and composed of those at the assistant director level and the program managers. The Steering Committee would be responsible for preparation of the long-range plans and for major program and resource allocation decisions. The Committee should be a decision-making entity which, in carryout out PPBS-like activities, follows a step-by-step procedure as follows:

(1) The Committee assesses the existing levels of resources and establishes cost parameters (e.g., costs per man/year) for use by the program managers in their planning efforts. These costs are projected for a five year planning horizon, subject to annual review and modification.

(2) Having agreed upon resource prices, the Committee directs that benefit-cost analyses be carried out within individual programs.

(3) At some point, the Committee receives the appropriation for the upcoming fiscal year from the Bureau of the Budget. This becomes the budget constraint for short term (one year) planning and resource allocation.

(4) The benefit-cost analyses performed by the individual program staffs are reviewed by the Committee.

(5) The cost estimates are revised to incorporate any complementarities (e.g., joint costs) among the individual programs. Concurrently, an approximate cutoff point for benefit/cost ratios for the individual programs is established (or a higher discount rate on future benefits assigned) in order to remain within the limits of the current budget constraint imposed by the Bureau of the Budget.

(6) Program budgets are drafted by application of the cutoff benefit-cost ratio criterion. This requires each program manager to eliminate those sub-programs that have lower benefit/cost ratios than the initial one, or to decrease the level of output of particular sub-programs. The five-year program plans should also be revised to incorporate the updated costs and cutoff ratio.

(7) On the basis of the "optimal" solution achieved in steps five and six, funding is allocated to the individual programs. Controls are established to monitor the execution of the programs selected. While these controls are determined by the Steering Committee, responsibility for program control continues to be in the hands of the program managers.

(8) The Committee now assembles the five-year Program Memorandum for submission to the Bureau of the Budget. This document outlines each of the programs as well as the alternative program elements for achieving the various levels of output associated with the objectives. It should include a general statement of the aggregate benefit-cost ratio if resources are

allocated as shown by the Geologic Division.

This procedural framework would not only be useful for complying with the PPBS requirements of the Bureau of the Budget, but also would be beneficial to the Geological Survey for planning and coordinating its various activities. The professionalism of the organization would be maintained, but the geologists would be aware of programs having financial support for the coming fiscal year when requesting assignment to projects of interest to them. Within the financial constraints, the geologist exercises his choice. However, he may not be able to have his first choice since that project may not have been funded or, if funded, the allocated amount may have been committed to other researchers. While this may cause some personnel difficulties, a financial constraint would seem to be more readily acceptable by a professional than a direct order from a supervisor.

Summary

Under PPBS the Geologic Division of the Geological Survey, like most other agencies, has faced two kinds of problems: compliance with the directive to implement the new system and organizational change to make it effective in the long run. It must evaluate its present and potential activities in a quantitative way and submit a suitable Program Memorandum and other documents. In the PPBS framework such an evaluation means, first, generating hypothetical alternative projects or program elements. The program elements are then evaluated and compared by cost effectiveness criteria, and "optimal" programs established. Second, the programs so developed almost invariably call for departures from existing organizational structure, given their new orientation

toward specific sub-objectives and/or toward users of Division outputs. These changes in structure have to be made.

After a description of the present activities of the Geologic Division, we attempted benefit-cost analyses of three current activity areas. These analyses were applied to parts of Regional Geology, Engineering Geology and Experimental Geology. The calculations of benefits for regional maps for the minerals and fuels industries, and for engineering geology, involved measurement of the effects of changes in the current levels of these activities. In contrast, earthquake forecasting is a research program for which there is no present output comparable to geologic maps and reports, so that there is no current social benefit. Forecasts of future benefits were made directly in this last case. These calculations were intended to illustrate an approach to thorny problems in measurement rather than to provide definitive benefit-cost ratios; but they suggest that resources might usefully be allocated toward engineering mapping at the expense of hazards research and mineral mapping.

The limits on our knowledge of present and future national objectives which affect the Geologic Survey make it unwise for us to attempt to delineate sub-objectives and recommend a new organization based on new programs. Such an approach may be long in coming in any case. But we do recommend a reorganization based on six major program areas, where these are determined by present and potential users of the output of the Geologic Division. They are: Basic Research, Public Policy Programs, Geologic Hazards, Economic Programs, Engineering Programs and Consulting Services. For implementing PPBS techniques a Steering Committee was proposed which would set the guidelines for developing plans and would coordinate the iterations required to develop an overall efficient set of plans and budgets.

BASEMENT

Date Due

~~[illegible]~~

DEC 31 '77

~~MAY 29 '78~~

~~JUN 02 '78~~

AUG [illegible] 1985

Lib-26-67

MIT LIBRARIES
3 9080 003 904 924
332-68

MIT LIBRARIES
3 9080 003 904 981
334-68

MIT LIBRARIES
3 9080 003 873 962
335-68

HD

MIT LIBRARIES
3 9080 003 873 772
336-68

MIT LIBRARIES
3 9080 003 904 973
337-68

MIT LIBRARIES
3 9080 003 873 921
338-68

MIT LIBRARIES
3 9080 003 905 277
339-68

MIT LIBRARIES
3 9080 003 905 269
340-68

MIT LIBRARIES
3 9080 003 874 309
341-68